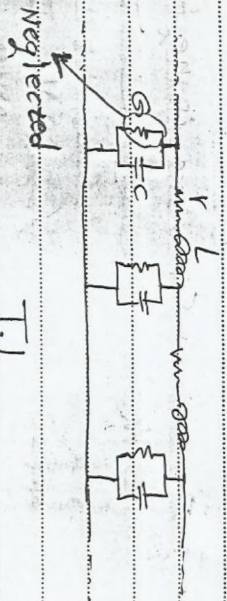


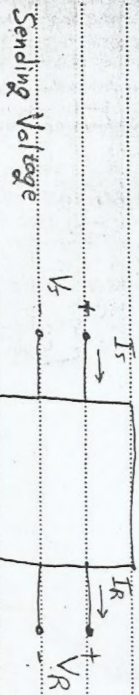
Subject:

Transmission Line Modeling



Short Medium Long

T.L. $L < 80 \text{ km}$ $80 \text{ km} < L \leq 240 \text{ km}$ $L > 240 \text{ km}$



Sending Voltage

$$V_s = A * V_R + B * I_R$$

Receiving Voltage

$$I_s = C * V_R + D * I_R$$

Sending Current

Receiving Current

A, B, C, D → T.L. constants or parameters

Subject:

d)

~~11.76 * 10^-9 F/km~~

$$I_{ch} = I W CV$$

$$I_{ch} = 5 * 2\pi * 60 * 11.76 * 10^{-9} \frac{F}{km} \sqrt{3}$$

$$I_{ch} = 5 * 0.5631 \text{ A/km}$$

or

$$I_{ch} = 0.5631 \angle 90^\circ \text{ A/km}$$

$$Q_{3\phi} = \sqrt{3} V_L I$$

$$Q_{3\phi} = V_{ph} I$$

$$Q_{3\phi} = 3 Q_{ph}$$

$$Q_{3\phi} = \sqrt{3} * 220 * 10^3 * 0.5631 * 10^{-3} = 214.6 \text{ VAR}$$

(2)

(1)

Nominal Voltage

rect: Rated "

Ex 8

$$f = 60 \text{ Hz}$$

A 220 KV, 30 TL is 40 km, The resistance per phase is $0.15 \Omega/\text{km}$, and The inductance per phase is 1.3263 mH/km .

The shunt capacitance is ~~neglected~~ negligible. Use short

line Model to find the Voltage & power at Sending end,

and The V.R, & γ when The line is supplying ~~at~~ 30 loads

Ⓐ 381 MVA at 0.8 p.f lagging at 220 KV, VR(LL)

Ⓑ 381 MVA at 0.8 p.f ~~lagging~~ leading at 220 KV.

Solution

Notes

$$V_s = A V_R + B I_R$$

$$I_s = C V_R + D I_R$$

$$R = 0.15 \times 40 = 6 \Omega$$

$$X_L = \omega L = 2\pi \times 60 \times 1.3263 \times 10^{-3} \times 40 = 20 \Omega$$

$$Z = R + jX_L = 6 + j20 \quad Z = 20.88 \Omega \quad \angle 73.3^\circ$$

$$A = 1, B = Z = 20.88 \Omega \quad \angle 73.3^\circ, C = 0, D = 1$$

$$V_R = \frac{220 \text{ kV}}{\sqrt{3}} = 127 \text{ kV} \quad \angle 0^\circ$$

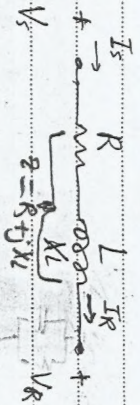
phase to neutral

inductance per line

30 loads at P

Subject:

Short line Model



Capacitance is neglected

$$V_s = V_R + Z I_R \quad ; \quad A = 1, B = Z$$

$$I_s = I_R \quad ; \quad C = 0, D = 1$$

Voltage regulation % VR

$$\% VR = \frac{|V_{RNL}| - |V_{R(All load)}|}{|V_{R(All load)}|} \times 100$$

$$|V_{R(0)}|$$

V_{RNL} Receiving Voltage at No load

$V_{R(0)}$ " " " " " "

$$\eta\% = \frac{P_o}{P_i} \times 100 = \frac{P_R}{P_i} \times 100$$

efficiency

at No load, $I_R = 0$

$$V_{RNL} = \frac{V_s}{A}$$

Subject:

$$S' = \frac{P}{\cos \phi} + j \frac{Q}{\sin \phi} = 322.8 + j 288.6 \text{ MVA}$$

MVA
MW

$$|V_R(\text{net})| = \frac{220}{A} V_s = \frac{250k}{1} = 250kV$$

$$\%VR = \frac{250 - 220}{220} \times 100 = 13.64\%$$

$$\%V_R = \frac{P_R}{P_s} \times 100 = \frac{381 \times 10^8}{322.8} \times 100 = 94.42\%$$

$$P_s = P_R + P_{\text{losses}} \rightarrow 3RI^2$$

$$P_{\text{losses}} = 18 \text{ MW}$$

$$|V_s| = 210.26 \text{ kV}$$

active power

$$\text{Apparent power } S' = P + jQ \rightarrow \text{Reactive power}$$

$$S' = \sqrt{P^2 + Q^2} \quad P \cos \phi = \frac{P}{S'}$$

$$S'_{3\phi} = \sqrt{3} V_{LL} I_{L}^* \quad S'_{1\phi} = V_{ph} I^*$$

$$|I_R| = \frac{381}{\sqrt{3} \times 220} = 1000 \text{ A} = 1 \text{ kA}$$

$$I_R = 1 \text{ kA} \angle -36.87^\circ$$

$$V_s = A V_R + B I_R$$

$$= 1 \times 127kV \angle 0^\circ + 20.88 \angle 73.3^\circ \times 1k \angle -36.87^\circ$$

$$V_s = 144.3 \text{ kV} \angle 4.928^\circ$$

$$|V_{sLL}| = \sqrt{3} \times 144.3 = 250 \text{ kV}$$

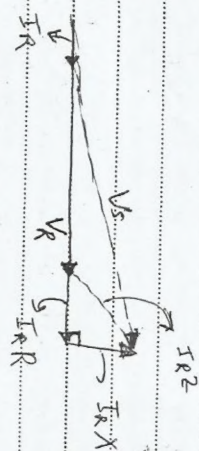
$$I_s = I_R = 1 \text{ kA} \angle -36.87^\circ$$

$$S'_{3\phi} = \sqrt{3} V_{sLL} I_s^*$$

$$S'_{3\phi} = \sqrt{3} (250k \angle 4.93^\circ) (1k \angle -36.87^\circ) = 433 \angle 41.8^\circ \text{ MVA}$$

8 5

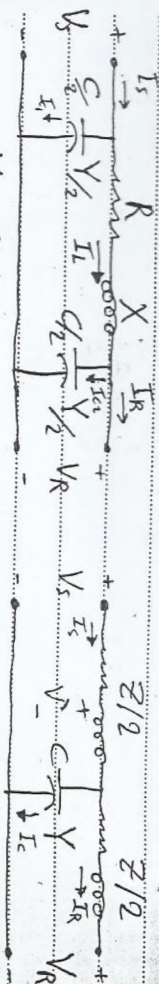
Unity power factor $P.F. = 1$



Medium line Model 80 [80k ≤ L ≤ 240km]

π Model

T Model



$$Y = j\omega C$$

$$Y = G + jB$$

π Model 8

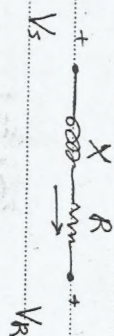
$$V_s = A V_R + B I_R$$

$$I_s = C V_R + D I_R$$

General Equation

$$V_s = V_R + Z I_R$$

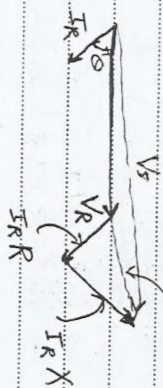
Subject:



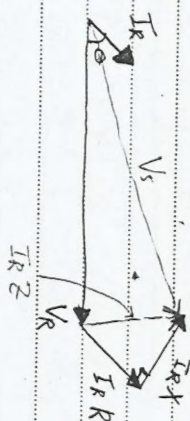
$$V_s = V_R + Z I_R$$

$$= V_R + (R + jX) I_R = V_R + R I_R + jX I_R$$

When lagging $\alpha I_R Z$



When Leading



Model 8

$$A = D = 1 + \frac{ZY}{2}$$

$$B = Z \left(1 + \frac{ZY}{4} \right)$$

$$C = Y$$

$$I_S = I_C + I_R = YV + I_R = Y \left(V_R + \frac{Z}{2} I_R \right) + I_R$$

$$I_S = YV_R + \frac{ZY}{2} I_R + I_R$$

$$I_S = \underbrace{YV_R}_C + \underbrace{\left(1 + \frac{ZY}{2} \right) I_R}_D$$

$$V_S = \frac{Z}{2} I_S + YV$$

$$V_S = \left(1 + \frac{ZY}{2} \right) V_R + Z \left(1 + \frac{ZY}{4} \right) I_R$$

Subject:

Note: $\{A=D\}$ always

$$I_L = I_C + I_R$$

$$I_C = \frac{Y}{2} V_R$$

$$\therefore I_L = \frac{Y}{2} V_R + I_R$$

$$\therefore V_S = V_R + Z \left(\frac{Y}{2} V_R + I_R \right)$$

$$V_S = V_R + \frac{ZY}{2} V_R + Z I_R$$

$$V_S = \left(1 + \frac{ZY}{2} \right) V_R + Z I_R$$

$$\therefore \boxed{A = 1 + \frac{ZY}{2}}$$

$$\boxed{B = Z}$$

$$I_S = I_C + I_L = \frac{Y}{2} V_S + \frac{Y}{2} V_R + I_R$$

$$I_S = \frac{Y}{2} \left[\left(1 + \frac{ZY}{2} \right) V_R + Z I_R \right] + \frac{Y}{2} V_R + I_R$$

$$I_S = Y \left(1 + \frac{ZY}{4} \right) V_R + \left(1 + \frac{ZY}{2} \right) I_R$$

$$\therefore \boxed{C = Y \left(1 + \frac{ZY}{4} \right)}$$

$$\boxed{D = \left(1 + \frac{ZY}{2} \right)}$$

$$S_{10} = \sqrt{3} V_L \times I_S^*$$

Reference

$$V_R = \frac{325 \text{ KV}}{\sqrt{3}} \angle 0^\circ = 187.64 \text{ KV} \angle 0^\circ$$

$$I_R = \frac{S^*}{\sqrt{3} V_R} = \frac{270 \text{ MVA}}{\sqrt{3} \times 325 \text{ KV}} = 479.64 \text{ A} \angle -8.81^\circ$$

$$V_S = A V_R + B I_R = 199.15 \text{ KV} \angle 4.01^\circ$$

$$I_S = C V_R + D I_R = 421.37 \text{ A} \angle -25.32^\circ$$

$$|V_{S/11} = \sqrt{3} V_S = 344.94 \text{ KV}$$

$$I_{S/11} = \sqrt{3} I_S = 729.94 \text{ A} \angle -25.32^\circ$$

$$S_{S/11} = 219478051.5 + j123316490.8 \text{ VA}$$

P [W] Q [VAR]

$$V_R \% = \frac{|V_{R(NL)}| - |V_{R(FL)}|}{|V_{R(FL)}|} \times 100$$

$$|V_{R(NL)}|$$

$$|V_{R(NL)}| = \frac{V_S}{A} \Big|_{I_R=0} = 348.78 \text{ KV}$$

$$|V_{R(FL)}| = 325 \text{ KV}$$

$$\therefore V_R \% = \frac{348.78 - 325}{325} \times 100 = 7.317\%$$

Subject:

Exo 8 A 345 KV, 30, T.L is 130 km long. The resistance per phase is 0.036 Ω/km and the inductance is 0.8 mH/km. The shunt capacitance is 0.0112 $\mu\text{F}/\text{km}$. The receiving load is 270 MVA with 0.8 P.f lagging at 325 KV. Use the medium line model to find the voltage & power at sending end and The V.R. $f = 60 \text{ Hz}$.

Solution

$$R = 0.036 \Omega/\text{km} \times 130 \text{ km} = 4.68 \Omega$$

$$X_L = \omega L = 2\pi \times 60 \times 0.8 \times 10^{-3} \times 130 = 39.267 \Omega$$

$$Z = 4.68 + j39.267 = 39.5 \angle 83.2^\circ \Omega$$

$$Y = G + jB = j \times 2\pi \times 60 \times 0.0112 \times 10^{-6} \times 130 = j0.000549 \text{ S}$$

$$A = \left(1 + \frac{ZY}{2}\right) = 0.989 \angle 0.07^\circ$$

$$B = Z = 39.5 \angle 83.2^\circ \Omega$$

$$C = Y \left(1 + \frac{ZY}{4}\right) = 5.460 \times 10^{-4} \angle 90.04^\circ \text{ S}$$

$$D = A = 0.989 \angle 0.07^\circ$$

$$\frac{dV(x)}{dx} = -Z I(x) \rightarrow [1]$$

$$I(x+\Delta x) = I(x) + y \Delta x V(x+\Delta x)$$

$$\Delta x \rightarrow 0$$

$$\frac{dI(x)}{dx} = -y V(x)$$

$$\frac{dI(x)}{dx} = -y V(x) \rightarrow [2]$$

$$\frac{d^2 V(x)}{dx^2} = -Z \frac{dI(x)}{dx}$$

$$\frac{d^2 V(x)}{dx^2} = -Z y V(x)$$

$$\frac{d^2 V(x)}{dx^2} - Z y V(x) = 0$$

attenuation constant

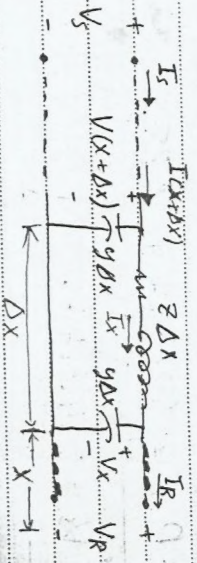
propagation constant $\gamma = \sqrt{ZY} = \alpha + j\beta \rightarrow$ phase constant

$$\frac{d^2 V(x)}{dx^2} - \gamma^2 V(x) = 0 \rightarrow [3]$$

Subject:

Long Line Model: $\geq 240 \text{ km}$

For short & medium line, the line parameters assumed lumped & not high accurate. For long line the exact effect of the distributed parameters must be considered. The expression of voltage & current at any point on the line are derived. Then based on these equations an equivalent π model is obtained.



$Z \triangleq$ Series impedance / unit length

$y \triangleq$ Shunt admittance / unit length

Consider a small segment of line Δx at distance x from the receiving end of the line.

$$V(x+\Delta x) = V(x) + Z \Delta x I(x)$$

$$Z I(x) = \frac{V(x+\Delta x) - V(x)}{\Delta x}$$

$$\lim_{\Delta x \rightarrow 0} \frac{V(x+\Delta x) - V(x)}{\Delta x} = \frac{dV(x)}{dx}$$

Subject:

$$V(x) = \left[\frac{V_R + Z_c I_R}{2} \right] e^{yx} + \left[\frac{V_R - Z_c I_R}{2} \right] e^{-yx}$$

$$I(x) = \frac{1}{Z_c} \left\{ \left[\frac{V_R + Z_c I_R}{2} \right] e^{yx} - \left[\frac{V_R - Z_c I_R}{2} \right] e^{-yx} \right\}$$

$$V(x) = \left(\frac{e^{yx} + e^{-yx}}{2} \right) V_R + Z_c \left(\frac{e^{yx} - e^{-yx}}{2} \right) I_R$$

$\cosh(yx)$ $\sinh(yx)$

$$I(x) = \frac{1}{Z_c} \frac{e^{yx} - e^{-yx}}{2} V_R + \frac{e^{yx} + e^{-yx}}{2} I_R$$

$$V(x) = \left[\cosh(yx) \right] V_R + \left[Z_c \sinh(yx) \right] I_R$$

A B

$$I(x) = \left[\frac{1}{Z_c} \sinh(yx) \right] V_R + \left[\cosh(yx) \right] I_R$$

C D

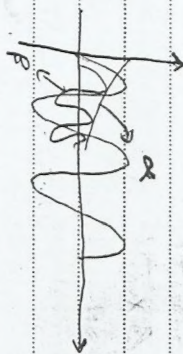
$$A = \cosh(yx)$$

$$B = Z_c \sinh(yx)$$

$$C = \frac{1}{Z_c} \sinh(yx)$$

$$D = \cosh(yx)$$

$$V = A V_R + B I_R$$



$$V(x) = A_1 e^{yx} + A_2 e^{-yx}$$

[14]

$$I(x) = \frac{1}{Z_c} \frac{dV(x)}{dx} = \frac{y}{Z_c} \left[A_1 e^{yx} - A_2 e^{-yx} \right]$$

[15]

$$= \frac{1}{Z_c} y A_1 e^{yx} - y A_2 e^{-yx}$$

$$I(x) = \frac{y}{Z_c} \left[A_1 e^{yx} - A_2 e^{-yx} \right]$$

To find A_1 & A_2

characteristic Impedance

at $x=0 \rightarrow V(x) = V_R$
 $I(x) = I_R$

$$A_1 = \frac{V_R + Z_c I_R}{2}, \quad A_2 = \frac{V_R - Z_c I_R}{2}$$

$$Z_c = \sqrt{\frac{L}{C}}$$

$$\frac{Y}{Z_c} = \frac{1}{Z_c} \frac{\cosh(\gamma L) - 1}{\sinh(\gamma L)} = \frac{1}{Z_c} \tanh\left(\frac{\gamma L}{2}\right)$$

$$\frac{Y}{Z_c} = \frac{1}{Z_c} \tanh\left(\frac{\gamma L}{2}\right) = \frac{Y}{Z_c} \tanh\left(\frac{\gamma L}{2}\right)$$

$$Z_c = \sqrt{\frac{L}{C}} \times \frac{\sqrt{L}}{\sqrt{C}} = \frac{L}{\sqrt{LC}} = \frac{L}{\sqrt{LC}} \rightarrow \text{total}$$

$$Y = \sqrt{\frac{C}{L}}$$

$$Z_c = Z_L$$

$$Z_c = \frac{Z}{\gamma L}$$

Voltage & Current Waves

$$V = \alpha + j\beta$$

$$\text{Velocity of propagation } v = \frac{\omega}{\beta}$$

$$\text{Wave length } \lambda = \frac{2\pi}{\beta}$$

Subject:

$$a \neq X = L$$

$$V(x) = V(L) = V_R$$

$$I(x) = I(L) = I_R$$

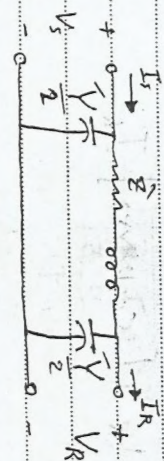
$$V_s = \left[\cosh(\gamma L) \right] V_R + \left[Z_c \sinh(\gamma L) \right] I_R$$

$$I_s = \left[\frac{1}{Z_c} \sinh(\gamma L) \right] V_R + \left[\cosh(\gamma L) \right] I_R$$

Notes

$$AD - BC = 1$$

Equivalent Circuit of long line



$$A = D = 1 + \frac{ZY}{2}$$

$$B = Z$$

$$C = Y \left(1 + \frac{ZY}{4} \right)$$

$$\tilde{Z} = Z_c \sinh(\gamma L) = \frac{Z_c \sinh(\gamma L)}{\gamma L}$$

$$A = 1 + \frac{\tilde{Z}Y}{2} = \cosh(\gamma L)$$

$$1 + \frac{\tilde{Z} \sinh(\gamma L)}{2} \cdot Y = \cosh(\gamma L)$$

Subject:

$$\cosh(\gamma L) = \frac{e^{\gamma L} + e^{-\gamma L}}{2}$$

$$e^{\gamma L} = \frac{e^{\gamma L} + e^{-\gamma L}}{2} \quad \left| \frac{2}{e^{\gamma L} + e^{-\gamma L}} \right|$$

$$e^{-\gamma L} = e^{-0.456} \quad \left| -27.22^\circ \right|$$

$$A = 0.8904 \quad \left| 1.3427^\circ \right|$$

$$B = Z_c \sinh(\gamma L)$$

$$Z_c = \sqrt{\frac{Z}{Y}} = \sqrt{\frac{0.4772}{5.105 \times 10^{-6}}} = 406.4 \quad \left| -5.48^\circ \right|$$

$$\sinh(\gamma L) = \frac{e^{\gamma L} - e^{-\gamma L}}{2} = 0.4597 \quad \left| 84.93^\circ \right|$$

$$B = 186.82 \quad \left| 79.45^\circ \right|$$

$$V_R = \frac{215}{\sqrt{3}} = 124.13 \text{ kV}$$

$$I_R = \frac{125}{\sqrt{3} \times 215 \times 1} = 335.7 \text{ A}$$

$$P_{3\phi} = \sqrt{3} V_{LL} I \cos \theta$$

Example 2

A single circuit 3 ϕ 60 Hz T.L is 230 mi long. The conductors are Roak with flat horizontal spacing 23.8 ft between conductors. The load on the line is 125 MW at 215 kV with 100% p.f. Find the sending end quantities & % V.R. Also find the wave length & velocity of propagation of the line.



Solution

$$Z = r + jX_L$$

from Table

$$r = 0.1603$$

$$X_L = X_a + X_d = 0.415 + 0.41127$$

$$Z = 0.1603 + j0.8277 \text{ mi}$$

$$Y = j \frac{1}{(0.095 + 0.1009) \times 10^{-6}} = 5.105 \times 10^{-6} \text{ S/mi}$$

$$\gamma L = 230 \sqrt{0.841 \times 5.105 \times 10^{-6}} \quad \left| 84.52^\circ \right|$$

$$X_L = 0.4772 \quad \left| 84.52^\circ \right|$$

$$X_L = 0.0456 + j0.4750 \quad \left| 84.52^\circ \right|$$

Line 8

Sov long model

$$V = V + jWL$$

$$Y = Y + jB = jWC$$

$$Y = jB = jWLC$$

$$Y = jB = jWLC$$

$$Z_c = \sqrt{\frac{Z}{Y}} = \sqrt{\frac{L}{C}}$$

$$A = \cos(\beta L)$$

$$B = jZ_c \sin(\beta L)$$

$$C = \frac{1}{Z_c} \sin(\beta L)$$

$$D = A$$

$$\cosh(\gamma L) = \cosh(j\beta L) = \cos(\beta L)$$

$$\sinh(\gamma L) = \sinh(j\beta L) = j \sin(\beta L)$$

$$V_s = \cos(\beta L) V_R + j Z_c \sin(\beta L) I_R$$

$$I_s = j \frac{1}{Z_c} \sin(\beta L) V_R + \cos(\beta L) I_R$$

$$I_s = \frac{1}{Z_c} \sinh(\gamma L)$$

For typical TL Z_c varies from 400 Ω for 69 kV
 → 250 Ω for Deale circuit 765 kV

$$V_s = A V_R + B I_R = 137.86 \sqrt{27.77} \text{ kV}$$

$$|V_s|_{LL} = \sqrt{3} (157.86) = 238.8 \text{ kV}$$

$$I_s = C V_R + D I_R = \frac{1}{Z_c} \sinh(\gamma L) V_R + \cosh(\gamma L) I_R$$

$$= 332.31 \sqrt{26.33} \text{ A}$$

$$P_R = \cos(27.77 - 26.33) = 0.9997 \approx 1$$

$$S_{3\phi} = \sqrt{3} V_{LL} I_s^* = 137400.937.2 + j 3453976.9 \text{ VA}$$

$$P = \frac{P_L}{Z_c L} = \frac{0.475}{230} = 0.002065 \text{ rad/mi}$$

$$\lambda = \frac{2\pi}{\beta} = \frac{2\pi \times 14}{0.002065} = 3043 \text{ mi}$$

$$V = 8\lambda = 60 \times 3043 = 182.580 \text{ mi/s}$$

800 MW
 $V_{LL} = 500 \text{ KV}$
 $P_f = 0.8$ lagging

$$A = \cos(\beta L) = \cos\left(1.259 \times 10^{-3} \times 300 \times \frac{180}{\pi}\right)$$

$$A = 0.9995$$

$$B = j Z_c \sin(\beta L) = j (290.43) \sin\left(1.259 \times 10^{-3} \times 300 \times \frac{180}{\pi}\right)$$

$$B = j 107.1$$

$$C = j \frac{1}{Z_c} \sin(\beta L)$$

$$C = j 1.2698 \times 10^{-3}$$

$$A = D = 0.9995$$

$$V_{Rph} = 288.7 \text{ KV } 0^\circ$$

$$I_R = \frac{800 \text{ M}}{\sqrt{3} \times 500 \text{ KV} \times 0.8} = 1.155 \text{ KA } -36.87^\circ$$

Subject:

Saadat 5-58

ex: A 3ϕ , 60 Hz , 500 KV T.L is 300 km long. The line inductance is 0.97 mH/km/ph & its capacitance is 0.015 μF /km/ph. Assume lossless line

a) Determine B , Z_c , V , λ

b) The receiving end rated load is 800 MW , 0.8 lagging at 500 KV , Determine The sending end quantities & $\% \text{ VR}$

Solution

$$B = W \sqrt{LC} = 2\pi f \sqrt{LC}$$

$$B = 2\pi (60) \sqrt{0.97 \times 10^{-3} \times 0.015 \times 10^{-6}} = 1.259 \times 10^{-3} \text{ rad/Km}$$

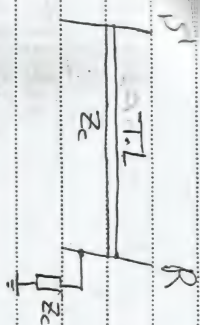
$$Z_c = \sqrt{\frac{L}{C}} = \sqrt{\frac{0.97 \times 10^{-3}}{0.015 \times 10^{-6}}} = 290.43 \Omega$$

$$V = \frac{W}{B} = \frac{2\pi (60)}{(1.259 \times 10^{-3})} = 299436.9 \text{ Km/s}$$

$$\lambda = \frac{2\pi}{B} = 4990.6 \text{ Km}$$

$$V = \frac{1}{\sqrt{LC}}, \lambda = \frac{V}{f}$$

Impedance Loading: SIL



The load corresponding to Z_c at V_{rated} is known as SIL

$$SIL = 3 V_R I_R^* = 3 \frac{|V_R|^2}{Z_c} = \frac{|V_{rated}|^2}{Z_c}$$

$$I_R = \frac{V_R}{Z_c}$$

$$SIL = \frac{|V_{rated}|^2}{Z_c} \quad [MW]$$

$$V_s = \cos(\phi_L) V_R + j Z_c \sin(\phi_L) I_R$$

$$V_s = \cos(\phi_L) V_R + j Z_c \sin(\phi_L) \frac{V_R}{Z_c}$$

$$V_s = V_R [\cos(\phi_L) + j \sin(\phi_L)]$$

$$V_s = V_R \angle \beta_L$$

$$V_s = A V_R + B I_R = 356.6 \text{ kV} \angle 16.11^\circ$$

$$V_{NL} = 617.6 \text{ kV} \angle 16.11^\circ$$

$$I_s = C V_R + D I_R = 8.9026 \text{ kA} \angle -17.9^\circ$$

$$P_f = \cos(16.11 + 17.9) = 0.829 \quad \text{lagging}$$

$$S = \sqrt{3} V_{NL} I_s^* = (800.4 + j540.1) \text{ MVA}$$

$$\begin{matrix} P \\ MW \\ Q \\ MVAR \end{matrix}$$

$$V_R = \frac{|V_{NL}| - |V_{fL}|}{|V_{fL}|}$$

$$|V_{NL}| = \frac{|V_s|}{A} = \frac{617.6 \text{ kV}}{0.9295} = 664.4 \text{ kV}$$

$$V_R = \frac{664.4 - 500}{500} = 0.3289$$

$$V_R \% = 32.89 \%$$

Subject:

Complex Power flow ~~through~~ T.L. :-

$$A = |A| \angle \theta_A, \quad B = |B| \angle \theta_B$$

$$V_S = |V_S| \angle \delta, \quad V_R = |V_R| \angle \phi$$

$$V_S = A V_R + B I_R$$

$$I_R = \frac{V_S - A V_R}{B} = \frac{|V_S| \angle \delta - |A| \angle \theta_A * |V_R| \angle \phi}{|B| \angle \theta_B}$$

$$I_R^* = \frac{|V_S| \angle \theta_R - \delta}{|B|} - \frac{|A| |V_R| \angle \theta_B - \theta_A}{|B|}$$

$$S_{R(3\phi)} = \frac{3 |V_S| |V_R| \angle \theta_R - \delta}{|B|} - \frac{3 |A| |V_R|^2 \angle \theta_B - \theta_A}{|B|}$$

$$S_{R(3\phi)} = \frac{|V_S| \angle \theta_R - \delta}{|B|} - \frac{|A| |V_R| \angle \theta_B - \theta_A}{|B|}$$

$$S_{R(3\phi)} = 3 V_R I_R^* = P_{R(3\phi)} + j Q_{R(3\phi)}$$

$$\frac{|V_S| |V_R| \cos(\theta_R - \delta) - |A| |V_R|^2 \cos(\theta_B - \theta_A)}{|B|}$$

$$Q_{R(3\phi)} = \frac{|V_S| |V_R| \sin(\theta_R - \delta) - |A| |V_R|^2 \sin(\theta_B - \theta_A)}{|B|}$$

for lossless

$$\theta_R = 0, \quad \theta_B = 90, \quad B = j X = j Z \sin(\phi_1)$$

$$\cos(90 - \delta) = \sin(\delta)$$

$$P_{R(3\phi)} = \frac{|V_S| |V_R| \sin(\delta)}{|B|}$$

$$\sin(90 - \delta) = \cos(\delta)$$

$$Q_{R(3\phi)} = \frac{|V_S| |V_R| \cos(\delta) - |A| |V_R|^2}{|B|}$$

$$X = |B| = Z \sin(\phi_1)$$

Subject:

Illustrated in a purely resistive load. Determine the SE quantities & VR When the receiving end load is



$$GMR_D = \sqrt[3]{14 \times 14 \times 28} = 17.64 \text{ m}$$

$$GMR_L = 1.09 \sqrt[3]{1.43 \times 45^3} = 20.74 \text{ cm}$$

$$GMR_C = 1.09 \sqrt[3]{1.812 \times 45^3} = 21.97 \text{ cm}$$

$$L = 2 \times 10^{-7} \ln \left(\frac{GMR_D}{GMR_L} \right) = 8.89 \times 10^{-7} \text{ H/m}$$

$$C_m = \frac{2\pi\epsilon_0}{\ln \left(\frac{GMR_D}{GMR_C} \right)} = 19.67 \times 10^{-12} \text{ F/m}$$

$$Z_c = \sqrt{\frac{L}{C}} = 264.9 \Omega$$

$$\beta = \omega \sqrt{LC} = 1.2652 \times 10^{-6} \text{ rad/m}$$

$$\lambda = \frac{2\pi}{\beta} = 4966 \times 10^6 \text{ m} = 4966 \text{ km}$$

$$|SIL| = \frac{V_{rated}^2}{Z_c} = \frac{(765 \text{ kV})^2}{264.9} = 2209.2 \text{ MW}$$

$$\begin{bmatrix} V_s \\ I_s \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$$AD - BC = 1$$

$$\begin{bmatrix} V_R \\ I_R \end{bmatrix} = \begin{bmatrix} D & -B \\ -C & A \end{bmatrix} \begin{bmatrix} V_s \\ I_s \end{bmatrix}$$

$$V_R = DV_s - BI_s$$

$$I_R = -CV_s + AI_s$$

Problem 5-8:

A 3Ø 765 kV, 60 Hz transposed line is composed of 4 ACSR, 1,430,000 cmil, 45/7 Babo link core with flat horizontal spacing of 14m. The conductors have diameter of 3625 cm & GMR of 1.429 cm. The bundle spacing is 45 cm. The line is 436 km long. Assume lossless line.

- Calculate Z_c , β , λ , SIL , ABCD constant
- The line delivers 9000 MVA at 0.8 lagging P.F. at 765 kV. Determine the S.E. quantities & VR.
- Determine the R.E. quantities when 1920 MW R.E. are being transmitted at 765 kV. The sending end.

Subject:

$$V_L = 514.82 \text{ kV} \angle 18.15^\circ$$

$$I_S = 1.1 \text{ kA} \angle -2.43^\circ$$

$$|V_{SL}| = 896.9 \text{ kV}$$

$$S_{SD}^* = \sqrt{3} V_{LL} I_S^*$$

$$S_{SD}^* = \sqrt{3} \times 896.9 \text{ kV} \angle 18.15^\circ \times 1.1 \text{ kA} \angle 2.43^\circ$$

$$S_{SD}^* = (1518.1 + j 894.5) \text{ MVA}$$

Pending = Preceiving
lossless line

$$S_{3\phi}^* = (1920 + j 600) \text{ MVA}$$

$$V_{SL} = 765 \text{ kV} \angle 0^\circ$$

$$V_R = DV_S - RI_S$$

$$I_R = -CI_S + AI_S$$

$$V_{SL} = \frac{765 \text{ kV}}{\sqrt{3}} = 441.67 \text{ kV} \angle 0^\circ$$

$$S_{3\phi CV} = 2011.56 \text{ MVA} \angle 17.35^\circ$$

$$I_S = 1518.1 \text{ A} \angle -17.35^\circ$$

$$A = \cos(\theta_L) = \cos(1.2652 \text{ rad} \times 400 \text{ V} \angle \frac{180^\circ}{\pi})$$

$$A = \cos(28.99) = 0.8747$$

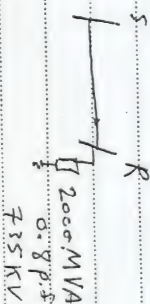
$$B = j Z_c \sin(\theta_L) = j (264.9) \sin(28.99)$$

$$B = j 128.39$$

$$C = j \frac{1}{Z_c} \sin(\theta_L) = j 1.833 \text{ A/V}$$

$$P = A = 0.8747$$

b)



$$V_S = AV_R + BI_R$$

$$V_R = \frac{735 \text{ kV}}{\sqrt{3}} = 424.35 \text{ kV} \angle 0^\circ$$

$$I_R = \frac{S^*}{\sqrt{3} V_{LL}} = \frac{2000}{\sqrt{3} \times 0.735} = 1511.02 \text{ A} \angle -36.87^\circ$$

$$3 V_R I_R^* = 1978.86 \text{ MVA } \angle 14^\circ$$

$$= 1920 \text{ MW} + j 479.2 \text{ MVAR}$$

$$\%VR = \frac{V_{RNL} - V_{REL} \times 100}{V_{RFL}}$$

$$|V_{RNL}| = |V_{SL}| = 874.69 \text{ kV}$$

$$\%VR = \frac{1874.691 - 1653.33}{1653.33} \times 100 = 33.88\%$$



$$V_R = 735 \text{ kV} = 424.35 \angle 0^\circ \text{ kV}$$

$$I_R = \frac{V_R}{R} = \frac{424.35 \angle 0^\circ}{248.5} = 1.69 \text{ kA } \angle 0^\circ$$

$$I_S = 1.604 \text{ kV } \angle 29.0^\circ$$

$$V_S = 424.48 \text{ kV } \angle 29.02^\circ$$

$$V_R = D_V - B_I$$

استحقاق

$$I_S = D_V - V_R = \frac{|A| \angle \theta_A |V_S| \angle \delta}{|B| \angle \theta_B} - \frac{|V_R| \angle \theta}{|B| \angle \theta}$$

$$I_S^* = \frac{|A| |V_S| \angle \theta_A - \delta}{|B|} - \frac{|V_R| \angle \theta}{|B|}$$

$$P_{S(s)} = 3 V_S I_S^* = \frac{3 |A| |V_S|^2 \angle \theta_A - \theta_A}{|B|} - \frac{3 |V_R| |V_S| \angle \delta + \theta}{|B|}$$

$$P_{S(s)} = \frac{|A| |V_S|^2 \angle \theta_A - \theta_A}{|B|} - \frac{|V_R| |V_S| \angle \delta + \theta}{|B|}$$

$$V_R = (0.8747)(441.67 \angle 0^\circ) - (1.518 \angle 17.35^\circ)$$

$$V_R = 377.2 \angle -29.54^\circ \text{ kV}$$

$$|V_{RNL}| = \sqrt{3} \times 377.2 = 653.33 \text{ kV}$$

$$I_A = -C V_S + A I_R = 1.749 \text{ kA } \angle -43.35^\circ$$

$V_{rated} = V_{base}$ → in this case

$V_s = 230 \text{ kV}$, $V_{rated} = 220 \text{ kV}$

$V_{p.u.} = \frac{230}{220} = 1.045 \text{ p.u.}$

From ②

$P_{(3\phi)} = \frac{|V_s||V_r|}{|Z|} \times \frac{|V_r||V_r|}{|Z|} \sin \delta$
 $V_{rated} \times V_{rated} \times \sin \delta$

$P_{(3\phi)} = \frac{(V_{s(p.u.)})(V_{r(p.u.)})(S.I.)}{\sin \delta}$

Ex 6

A Three phase power 700 MW is to be transmitted to a substation located 315 km from the source of power. for a preliminary line design assume the following parameters. $V_s = 1$, $V_r = 0.9 \text{ p.u.}$

$X = 5000 \text{ km}$, $Z_c = 320 \Omega$, $\delta = 36.87^\circ$ assume lossless line

a) Based on the practical line loadability equation, determine the natural voltage level for the T.L.

b) for the transmission voltage level obtained in (a) calculate the theoretical maximum power that can be transferred by the T.L.

Subject:

practical loadability line:

$P_{(3\phi)} = \frac{|V_s||V_r|}{|B|} \cos(\theta_B - \delta) - \frac{|A||V_r|^2}{|B|} \cos(\theta_B - \theta_A) \rightarrow 0$

$P_{(3\phi)} = \frac{|V_s||V_r|}{|B|} \sin \delta \rightarrow$ ② lossless line

* Theoretical Maximum Real Power occurs when $\theta_B = \delta$

Power Transmission Capability:

The power handling ability of a line is limited by the Thermal loading limited by the Thermal loading limit Voltage limit & stability limit.

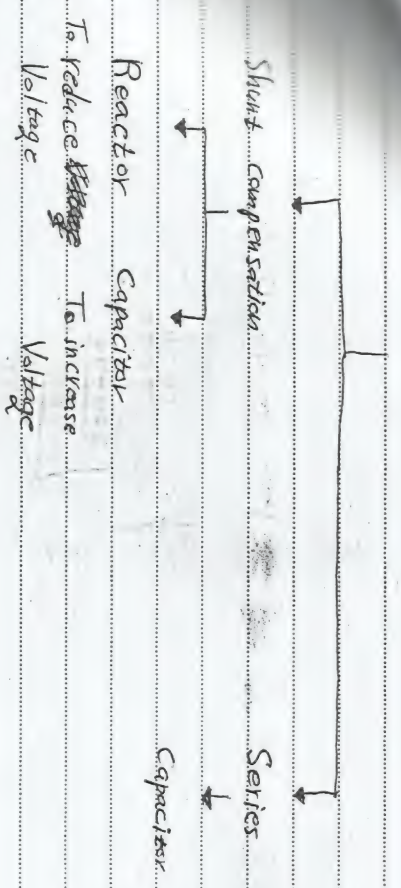
$S_{Thermal} = \text{Thermal Loading Limit} = 3 \frac{V_{rated}}{I_{Thermal}}$

For lossless line $\bar{X} = Z_c \sin(\beta l)$

Eq ② will be

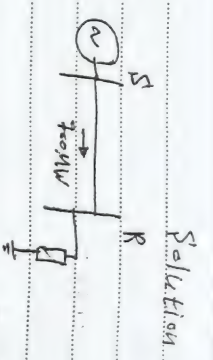
Per Unit System $P.U. =$

$P_{p.u.} = \frac{A_{real} \text{ Value}}{Base}$



Subject:

a)



Solution

$$P_d = \frac{|V_s| |P_d|}{|V_R|} \sin(\delta) \sin(\theta_L)$$

$$700 = \frac{1 \times 0.9 (SIL)}{\sin(22.68)} \sin(36.87) \quad A$$

$$SIL = 499.83 \text{ MW}$$

$$SIL = \frac{|V_{rated}|^2}{Z_c} \rightarrow V_{rated} = \sqrt{SIL (Z_c)}$$

$$V_{rated} = 400 \text{ kV}$$

b) When $\theta_R = \delta$; $\theta_R = 90$

$$P_d = \frac{|V_s| |V_R|}{X} \sin(\delta)$$

$$P_{3\phi} = \frac{(400 \times 1) (400 \times 0.9)}{(320) \sin(22.68)} = 1167 \text{ MW}$$

Subject:

Tutorial

1 / 1

$$\sinh(\gamma L) = \frac{e^{\gamma L} - e^{-\gamma L}}{2} = \frac{1 - e^{-\gamma L}}{2} = 0.5825 \angle 87.8^\circ$$

$$P = Z_c \sinh(\gamma L) = (282.6 \angle -24.5^\circ) (0.5825 \angle 87.8^\circ)$$

$$B = 164.6 \angle 85.4^\circ \quad \Omega$$

$$C = \frac{1}{Z_c} \sinh(\gamma L) = 2.061 \times 10^{-3} \angle 90.33^\circ \text{ S}$$

$$D = A = 0.8137 \angle 11.09^\circ$$

Prob 5-23

Determine the equivalent π circuit for the line in prob 5-14 & compared with the nominal circuit π circuit

$$\bar{Z} = Z_c \sinh(\gamma L) = 164.6 \angle 85.4^\circ$$

OK

$$\bar{Z} = \frac{Z_c \sinh(\gamma L)}{\gamma L} = \frac{164.6 \angle 85.4^\circ}{(0.3513 \angle 185.1^\circ) (500)} = 13.14 + j 18.1$$

$$\frac{1}{Z} \quad \downarrow \quad \gamma L$$

Glover / Prob 5-14

A 500 km, 500 kV, 60 Hz, 30 T.L line $Z = 0.03 + j0.35 \Omega/\text{km}$
 $\gamma = j 4.4 \times 10^{-6} \text{ S/km}$

Calculate \bar{Z}_c \bar{Y}_L , ABCD

* Solution *

$$Z_c = 0.3512 \angle 85.1^\circ$$

$$Y = 4.4 \times 10^{-6} \angle 90^\circ$$

$$Z_c = \sqrt{\frac{Z}{Y}} = \sqrt{\frac{0.351 \angle 85.1^\circ}{4.4 \times 10^{-6} \angle 90^\circ}}$$

$$Z_c = 282.6 \angle -24.5^\circ$$

$$\bar{Y}_L = \sqrt{ZY} L = \left(\sqrt{0.351 \angle 85.1^\circ \times 4.4 \times 10^{-6} \angle 90^\circ} \right) (500) \angle \frac{85.1^\circ + 90^\circ}{2}$$

$$\bar{Y}_L = 0.6216 \angle 87.55^\circ = 0.02657 + j0.6215 \text{ S}$$

(\bar{Y}_L) (\bar{Y}_L)

$$A = \cosh(\gamma L) = \frac{e^{\gamma L} + e^{-\gamma L}}{2} = \frac{e^{0.351 \angle 185.1^\circ} + e^{-0.351 \angle 185.1^\circ}}{2}$$

$$A = \frac{e^{0.351 \angle 185.1^\circ} + e^{-0.351 \angle 185.1^\circ}}{2}$$

$$A = 0.8137 \angle 11.09^\circ$$

$$\frac{1}{A} \quad \downarrow \quad \gamma L$$

The line in prob 5-16 has 3 ACSE 113,000 cmil Cond/ph. Calculate the theoretical max. real power that this line can be delivered & compare with thermal limit of the line. Assume $V_s = V_r = 1$ pu & unity power factor at the receiving end.

Solution

$$\theta_R = \delta$$

$$P_R = \frac{|V_L||V_R| \cos(\theta_R - \delta) - |A||V_R|^2 \cos(\theta_R - \theta_A)}{|B|}$$

Theoretical Max Power $\rightarrow \theta_R = \delta$

$$P_{3\phi} = \frac{500 \times 500}{164.6} - \frac{0.8137 (500)^2 \cos(85.412 - 1.69)}{164.6}$$

$$P_{3\phi} = 1397 \text{ MW}$$

$$I = \frac{P_{3\phi}}{\sqrt{3} V_L (\text{P.F.})} = \frac{1397 \text{ M}}{\sqrt{3} (500 \text{ kV}) (1)} = 1.613 \text{ kA}$$

from table

Approx.

Current

carrying capacity

$$1.11 \text{ kA} \Rightarrow 3 \times 1.11 \text{ kA} = 3.33 \text{ kA}$$

$$3.33 \text{ kA} > 1.613 \text{ kA}$$

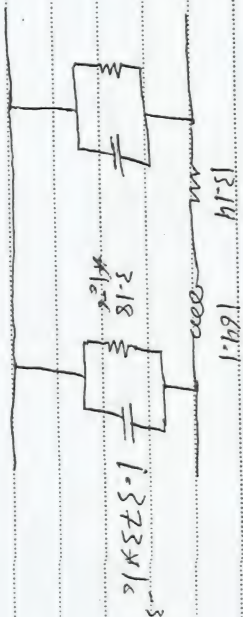
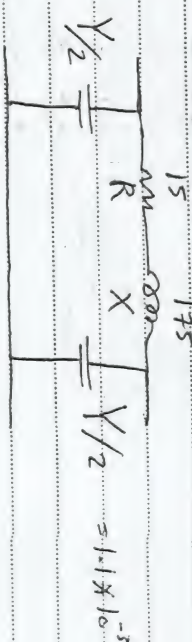
can be

$$\frac{Y}{2} = \frac{1}{Z_c} \tanh\left(\frac{g_L}{2}\right)$$

$$\frac{Y}{2} = \frac{Y}{2} \left(\frac{\tanh\left(\frac{g_L}{2}\right)}{\frac{g_L}{2}} \right) \rightarrow \frac{\cosh(g_L) - 1}{\sinh(g_L)}$$

$$\frac{Y}{2} = 1.137 \times 10^{-6} / 89.84^\circ$$

$$\frac{Y}{2} = 3.18 \times 10^{-6} + j 1.137 \times 10^{-5}$$



Relation between I_s & I_R is @ $V_s = V_R$

$$I_s = j \frac{1}{Z_c} \sin(\beta L) V_R + \cos(\beta L) I_R$$

$$V_R = j X_{Lsh} I_R$$

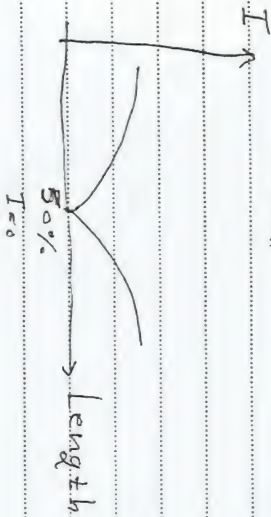
$$I_s = I_R \left[-\frac{1}{Z_c} \sin(\beta L) X_{Lsh} + \cos(\beta L) \right]$$

$$I_s = -I_R$$

$$V_m = \frac{V_R}{\cos(\beta \frac{L}{2})}$$

$V_m \equiv$ Voltage at mid of the line will max value

50% $V_s V_{max}$



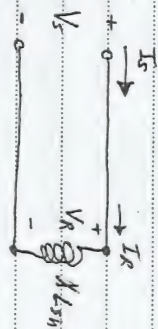
Subject:

Line Compensation:

II Shunt Compensation:

a) Shunt Reactor Compensation

Consider a reactor of reactance X_{Lsh} connected at the receiving end of the line



$$I_R = \frac{V_R}{j X_{Lsh}}$$

$$V_s = \cos(\beta L) V_R + j Z_c \sin(\beta L) I_R$$

$$V_s = \left[\cos(\beta L) + \frac{Z_c \sin(\beta L)}{j X_{Lsh}} \right] V_R$$

$$X_{Lsh} = \frac{\sin(\beta L)}{\frac{V_s}{V_R} - \cos(\beta L)} Z_c$$

$$\text{For } V_s = V_R \Rightarrow X_{Lsh} = \frac{\sin(\beta L)}{1 - \cos(\beta L)} Z_c$$

Subject:

$$Q_{1\phi} = V_{ph} I \sin \theta \quad ; \theta = 90^\circ$$

$$Q_{1\phi} = \frac{V_{ph}^2}{X} \rightarrow \text{receiving Voltage}$$

$$Q_{1\phi} = \frac{(500/\sqrt{3})^2}{1519.5} = 54.84 \text{ MVAR}$$

$$Q_{3\phi} = 3 Q_{1\phi} = 164.52 \text{ MVAR}$$

b) Shunt Capacitor Compensation

$$P_{R_{1\phi}} = \frac{V_{s1L} V_{R1L} \cos(\theta_R - \delta)}{|B|} - \frac{|A| V_{R1L}^2 \cos \theta_R}{|B|}$$

$$P_{R_{3\phi}} = \frac{V_{s1L} V_{R1L} \sin(\theta_R - \delta)}{|B|} - \frac{|A| V_{R1L}^2 \sin(\theta_R - \theta_A)}{|B|}$$

$f_{scr} \text{ lossless} \rightarrow \theta_A = 0, \theta_R = 90^\circ$

Example:

For T.L of example (*)

a) Calculate The receiving end Voltage When line is terminated in an open circuit & is energized with 500kV at the sending end.

b) Determine the reactance & MVAR of 3 phase Shunt reactor to be installed at The receiving end to keep the no load receiving end Voltage at the rated Value

Solution

$$P_L = 21.64 \quad Z_c = 290.43 \Omega \quad A = 0.9295$$

$$a) \quad V_s = 500 \text{ kV} \quad V_{RNL} = ? \quad V_{rated} = 500 \text{ kV}$$

$$V_s = A V_R + \frac{P_L}{V}$$

$$V_{RNL} = \frac{V_s}{A} = \frac{500/\sqrt{3}}{0.9295} = 310.57 \text{ kV}$$

$$V_{RNL} = \sqrt{3} V_{RNL\phi} = 537.9 \text{ kV}$$

$$X_{Lsh} = \frac{\sin(21.64)}{500 \text{ kV} - \cos(21.64)} = 1519.5 \Omega$$

Ans solved

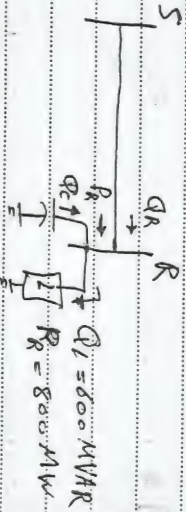
Only Series capacitors are installed at the mid point of the line providing 40% compensation. Find V_s & % $V.R$

Solution

$$Z_c = 290.43 \Omega \quad R_L = 21.64 \Omega$$

$$P_{R_{xy}} = \frac{V_s I_L}{X} \frac{V_R I_L}{X} \sin(\delta)$$

$$P_{R_{xy}} = \frac{V_s I_L}{X} \frac{V_R I_L}{X} \cos(\delta) = \frac{V_R I_L}{X} \cos(\delta)$$



$$800 = \frac{(500)(500)}{X^2} \sin(\delta)$$

$$X^2$$

$$X = Z_c \sin(\delta) = 107.11 \Omega$$

$$\delta = 20.04^\circ$$

$$P_{R_{xy}} = (500)(500) \cos(20.04) - \frac{(500)^2}{107.11} \cos(21.64) =$$

$$P_{R_{xy}} = 23.15 \text{ MWAR}$$

Subject:

Series Capacitor compensation

* Series capacitors are connected in series with the line.

* Usually located at the mid point of the line.

* Are used to reduce the series reactance between the load & supply point.

• To improve transient & steady state stability.

• Minimum voltage dip on load buses.

• More economical loading.

$$X_{ser} \cong \text{Series Capacitor reactance.}$$

$$\% \text{ Compensation} = \frac{X_{ser}}{X}$$

$$P_{R_{xy}} = \frac{V_s I_L}{X - X_{ser}} \sin(\delta)$$

Example:

A T.L in Ex. C) Supplies a load of 1000 MVA 0.8 P.F lagging at 500 kV.

a) Determine the MVAR & the capacitance of the shunt capacitor to be installed at the receiving end to keep the receiving end voltage at 500 kV when the line is energized with 500 kV at the sending end.

Subject:

$$A = \frac{1 + \tilde{Z} \tilde{Y}}{2} = 0.9577$$

$$B = \tilde{Z} = j64.27 \Omega$$

$$|V_R|_0 = \frac{500 \text{ KV}}{\sqrt{3}}$$

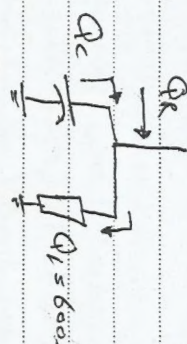
$$I_R = \frac{1000}{\sqrt{3} \times 500} = 1.1547 \angle -36.87^\circ \text{ KA}$$

$$V_S = A V_R + B I_R = 326.4 \angle 10.47^\circ \text{ KV}$$

$$|V_{SL}| = \sqrt{3} \times 326.4 = 565.4 \text{ KV}$$

$$V_{RCMU} = \frac{V_S}{A} = \frac{565.4}{0.9577}$$

$$V_R = \frac{V_{RCMU} - 500 \times 100}{500} = 18\%$$



$$Q_C = 600 - 23.15 = 576.85 \text{ MVAR}_c$$

$$X_C = \frac{V^2}{Q_C} = \frac{(500)^2}{576.85} = 433.38 \Omega$$

$$C = \frac{1}{\omega X_C} = \frac{1}{2\pi \times 60 \times 433.38} = 6.1 \mu\text{F}$$

b)

$$A = 1 + \frac{\tilde{Z} \tilde{Y}}{2} \quad B = \tilde{Z}$$

$$40\% = \frac{X_{Cser}}{X} \rightarrow X_{Cser} = 0.4 \times 107.11 = 42.84 \Omega$$

$$C_{ser} = \frac{1}{\omega X_{Cser}} =$$

$$X = 107.11 - 42.84 = 64.27 \Omega$$

$$\tilde{Z} = j64.27 \Omega$$

$$\tilde{Y} = j \frac{2}{Z_c} \tan\left(\frac{\beta L}{2}\right) = j \frac{2}{290.43} \tan\left(\frac{21.64}{2}\right)$$

$$\tilde{Y} = j 0.001316 \text{ S}$$

Subject:

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & -j50 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} 1 & -j50 \\ 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 0.96 & j39.2 \\ j0.002 & 0.96 \end{bmatrix}$$

Prob 5-15: Sadat

The ABCD constants of lossless line 30, 500KV T.L are $A=D=0.86$, $B=j130.2\Omega$, $C=j0.002S$

a) obtain the S.E.Q & VR When the line delivers 1000 MVA at 0.8 lagging P.F at 500KV to improve line performance, a series capacitance are installed at both ends in each phase at T.L As results of this compensated ABCD const. become

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & -j\frac{1}{2}X_c \\ 0 & 1 \end{bmatrix} \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} 1 & -j\frac{1}{2}X_c \\ 0 & 1 \end{bmatrix}$$

Where X_c is the total reactance of the Series Cap. $I_s X_c = 100\Omega$

- b) Determine the compensated ABCD
- c) Determine the S.E.Q & VR when line delivers 1000 MVA & 0.8 lagging P.F at 500KV

Solution

$$\begin{bmatrix} 1 & -jX_c \\ 0 & 1 \end{bmatrix} \text{ for Series capacitance}$$

$$\begin{bmatrix} 1 & 0 \\ -B_c & 1 \end{bmatrix} \rightarrow \text{for shunt}$$

ⓐ for reactance
ⓑ for capacitance

Prob 6-25 (Stevenson)

A 250 MVAR, 345KV, shunt reactor is connected to the receiving end of a line of Prob. (6-16), at No. load calculated the ABCD constant

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 0.8180 \angle 11.3^\circ & 172.2 \angle 84.2^\circ \\ 0.00193 \angle 70.4^\circ & 0.8180 \angle 11.3^\circ \end{bmatrix}$$

* Solution *

$$\begin{bmatrix} \hat{A} & \hat{B} \\ \hat{C} & \hat{D} \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$X_L = \frac{(345)^2}{250} = 470.1 \Omega \angle 90^\circ$$

$$B_L = \frac{1}{X_L} = 0.0021 \angle -90^\circ$$

Ex 6-7 Stevenson

Find The VR of line of Ex () When a shunt reactor is connected at the receiving end of the line during No load conditions if the reactor compensates 70% of total shunt admittance of the line.

Previous Ex:

$$Y = 5.105 \times 10^{-6} \text{ S/mi}$$

Solution

$$\text{For entire line } B_C = 5.105 \times 10^{-6} \times 230 = 0.001174 \text{ S}$$

$$B_L = 0.7 \times 0.001174 = 8.218 \times 10^{-4} \text{ S}$$

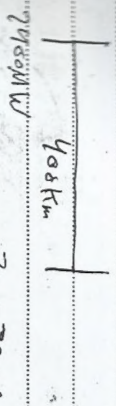
$$\begin{bmatrix} \hat{A} & \hat{B} \\ \hat{C} & \hat{D} \end{bmatrix} = \begin{bmatrix} 0.8904 \angle 1.34^\circ & 186.78 \angle 79.46^\circ \\ 0.001131 \angle 70.42^\circ & 0.8904 \angle 1.34^\circ \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \hat{A} & \hat{B} \\ \hat{C} & \hat{D} \end{bmatrix} = \begin{bmatrix} 1.0411 \angle -0.4^\circ & 86.78 \angle 79.46^\circ \\ 4.01 \times 10^{-4} \angle 88.7^\circ & 1.0411 \angle -0.4^\circ \end{bmatrix}$$

$$V_{RNL} = V_{RNL} - V_{RFL} \times 100 =$$

$$V_{REL}$$

$$V_{NL} = \frac{V_S}{A}$$



$Z_L = 300 \Omega$
 $Z_c = 290 \Omega$
 $Z_{total} = 590 \Omega$
 $V_L = 765 kV$
 $V_c = 5000 kV$

the practical line loadability may be based on a load angle of $35^\circ \rightarrow \delta = 35^\circ$

$|V_s| = 1 p.u.$
 $|V_r| = 0.9 p.u.$

Calculate the number of 3d transmission circuits required for each voltage

Solution

$P = \frac{|V_s| |V_r| \sin \delta}{X_{TL}}$

kV	$X_{TL} (M\Omega)$	$P (MW)$	N
345	320.0	371.95	400
500	290.0	862.07	923.3
765	265.0	2208.4	9365

number of towers

number of towers	if tower	if circuit
3	7400	400
2	7400	923.3
1	7400	2400

only 2400 is 765 kV line V

$G = 24$

The shunt admittance of a 300mi T.L is $Y = 6.87 \times 10^{-6} S/mi$ Calculate ABCD constant of a shunt reactor that will compensate for 60% of the total shunt admittance.

Solution

$B_1 = 0.6 * 6.87 \times 10^{-6} * 300 = 0.001237 S$

$\left[\begin{matrix} 1 & 0 \\ 0.001237 & 1 \end{matrix} \right]$

5-13 Sadat

Look for it